PATENT

SPECIFICATION

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COMBINED PRE-TREATMENT PROCESS FOR ENABLING FEED MATERIAL TO BE CHARGED IN DIRECT REDUCTION PROCESSES

CROSS REFERENCE TO RELATED APPLICATION

This application claims the benefit of U.S. Provisional Application No. 60/450,855, filed February 28, 2003.

FIELD OF THE INVENTION

The present invention relates to a method and apparatus for pre-treatment of solid lump feed material for gas and pellet/lump-based moving bed direct reduction processes, and more particularly to a method and apparatus for storing and pre-drying the solid lump feed prior to charging in the direct reduction furnace, followed by raising the effective reducing temperature throughout the moving bed.

BACKGROUND OF THE INVENTION

In a shaft furnace reduction process, iron ore or iron oxide in lump or pelletized form is fed into the upper portion of the furnace to form a burden of such lumps and/or pellets. Reducing gas is introduced into the mid-portion of the shaft furnace, usually about the periphery, through a bustle and tuyere arrangement. The reducing gas introduction temperature is generally about 850C, which will not cause the burden to melt. The reducing gas moves upward through the burden, heating the burden and reacting with the iron oxide in it to form metallized iron. The reacted gas is removed from the top of the furnace, and the reduced iron pellets and/or lumps continue their downward movement, are usually cooled in the lower portion of the furnace, and are discharged for further use The efficiency of thermal and chemical exchange between the burden and the gas is highly related to the amount of fines generated within the furnace due to degradation of the lumps or pellets occurring from thermal shock and/or from reduction at low temperatures (less than about 750C).

DESCRIPTION OF THE PRIOR ART

Applicants are aware of the following US Patents concerning moving bed direct reduction processes:

Patent No.	Issue Date	Inventor	Title
6,475,264 B1	11-05-2002	Dry	DIRECT SMELTING PROCESS
6,395,056	05-28-2002	Villareal-Trevino et al	METHOD FOR THE HEAT TREATMENT OF IRON ORE LUMPS IN A REDUCTION SYSTEM

6,379,421 B1	04-30-2002	Salinas-Fernandez	METHOD AND APPARATUS REMOVING UNDESIRABLE METALS FROM IRON-CONTAINING MATERIALS
6,277,324 B1	08-21-2001	Joo, *et al.*	APPARATUS FOR MANUFACTURING MOLTEN PIG IRON AND REDUCED IRON BY UTILIZING A FLUIDIZED BED
6,224,649 B1	05-01-2001	Villarreal-Trevino	METHOD AND APPARATUS FOR REDUCING IRON-OXIDES-PARTICLES HAVING A BROAD RANGE OF SIZES
6,132,489	10-17-2000	Villareal-Trevino	METHOD AND APPARATUS FOR REDUCING IRON-OXIDES-PARTICLES HAVING A BROAD RANGE OF SIZES
5,785,733	07-28-1998	Lee, *et al.*	FLUIDIZED BED TYPE REDUCTION APPARATUS FOR IRON ORE PARTICLES AND METHOD FOR REDUCING IRON ORE PARTICLES USING THE APPARATUS
5,961,690	10-05-1999	Kepplinger, *et al.*	PROCESS FOR PRODUCING MOLTEN PIG IRON OF LIQUID STEEL PREPRODUCTS AND PLANT FOR CARRYING OUT THE PROCESS
5,531,424	07-02-1996	Whipp	FLUIDIZED BED DIRECT REDUCTION PLANT
4,978,387	12-18-1990	Kepplinger	PROCESS FOR THE PRODUCTION OF MOLTEN PIG IRON
3,591,363	07-06-1971	D.L. Campbell	RADIANT HEATED IRON ORE REDUCTION PROCESS
3,295,956	01-03-1967	T.H. Whaley	ORE REDUCTION
2,877,107	03-10-1959	J.F. Magness	FINES HANDLING PROCESS

Villarreal-Trevino US Patent 6,395,056 teaches a method for handling a feed material with a high percentage of fines by feeding such material to a preheating device, wherein the particulate material is heated to a temperature above 600C in a non-reducing atmosphere, as a preheating step just prior to the step of charging the feed material into the furnace. The process of this patent attempts to preserve the strength of the iron ore particles, allowing the use of mechanically weak iron-oxide-containing particles. Therefore, their invention addresses degradation occurring during the reduction of the iron oxides, at temperatures above 600C. However, some iron oxides may have, as a main cause of degradation in the direct reduction furnace, reduced ability to resist the thermal shock occurring when the material is charged into the furnace. Furthermore, some sedimentary lump ores, due to their peculiar morphology, need to release internal stresses prior to being subjected to high temperatures. These stresses may be released, either by increasing the lump storage time, or by pre-drying the lump at low temperatures (around 200C), or by a combination of both.

SUMMARY OF THE INVENTION

The invented process is a pre-treatment for gas-based moving bed shaft furnace direct reduction processes, and is particularly useful with Midrex and Hyl Processes. Existing commercial iron ore reduction plants producing Direct Reduced Iron (DRI) rely on the feeding of pellets to maintain productivity of the furnace and homogeneity of the final DRI product. The most commonly used processes are very sensitive to finely divided (less than 6mm) particulate material, denoted "fines" which are generated from the lumps or pellets that are fed to the reducing furnace during operation. Such generated fines will partially fill the interstices between the pellets and/or lumps, restricting the flow of hot reducing gas, and causing "channeling" of the gas. This results in localized hot spots within the furnace, which can cause the formation of incipiently fused pellets or lumps, called clusters, which in turn can cause

furnace blockage. This can also result in the metallization of the product not being homogenous.

Due to the non-existence of microscopic hot bonds in lump ores, which would increase internal strength, lump ores generally have a greater tendency to produce fines than do pellets, when charged to a direct reduction furnace. In order to limit the amount of fines generated within the furnace, the proportion of lump ores fed to the furnace must be limited, in the vast majority of the cases.

Lump ore is just crushed and screened ore, and the lumps are not industrially produced as are pellets. Thus the cost of lump is less than the cost of the same weight of pellets. Any restriction on the amount of lump that can be used as a starting material becomes a financial penalty for the operation. Since the iron ore feed material is typically half or more of the cost of production of DRI, such a financial penalty can be significant.

The present invention pre-treats the feed material introduced to the direct reduction furnace, significantly reducing generation of fines. The invented process can be modified to be effective with a particular plant design.

It is known that sedimentary lump ores, such as naturally humid Corumba lump ore, have very little resistance to the combined effect of thermal shock and reduction at low temperatures, which fragment the lump, eventually resulting in a very high generation of fines (on the order of 40% of the initial weight) within the direct reduction furnace. It has now been determined that a combined pretreatment of Corumba lump ore will cause a dramatic reduction in fines generation: pretreatment combines storage in piles followed by predrying at low temperatures (< 200C), which is followed by low-temperature reduction in the furnace, the furnace having an enhanced thermal profile, with an increase in its local and average temperatures. The cause of such mechanical weakness is attributed to the microstructure of

Corumba lump ore, which is mainly constituted of micropores, as opposed to the widely known metamorphic lump ores, wherein the pores are usually larger in size. Therefore, an accentuated thermal shock drives out the retained moisture at a very high rate, resulting in the weakening of the microstructure and eventually leading to the generation of fines. In addition, it is understood within the direct reduction industry that reduction in the temperature of 500 - 750C within the furnace zone above the reduction zone results in low temperature decrepitation. The applicants have determined that the less reduction of ore that occurs at a temperature less than 800C, the fewer fines are generated due to low temperature decrepitation. To achieve this, an enhanced thermal profile is provided in the direct reduction furnace, which increased the average temperature throughout the furnace.

It has also been determined that by storing Corumba lump ore for a predetermined and controlled time, followed by pre-drying the ore at a controlled rate/temperature and, finally, by operating the furnace at average temperatures higher than current operations, the amount of fines generated by Corumba lump ore is reduced dramatically to less than 10%. It is important to note that, although the invented pretreatment might also have an effect on metamorphic lump ores, a dramatic reduction in fines generation is not expected to be obtained in such case, given that the phenomena occurring during the invented pretreatment are intimately associated with the sedimentary nature of Corumba lump ore.

The reduction in fines generation will nonetheless increase the productivity of the direct reduction furnace. Metallized DRI fines have a substantially lower commercial value than the metallized DRI lump, and handling and disposal of unnecessary fines is costly. Productivity of the DRI furnace may also be increased by operating the furnace at higher temperatures, due to the lower residence time of the burden in the furnace. The increase in productivity, although likely to be at a higher cash cost, spreads the fixed costs of the plant, including capital costs, over greater volumes of product, improving the overall economics of the direct reduction process and the plant. As for thermal shock, it has been determined that: when lump ore is

pretreated, a higher thermal shock is acceptable between the lump charged at the top and the gas at a higher temperature, because the microstructural changes undergone by the lump during pretreatment increase its mechanical strength and resistance to abrasion within the furnace.

OBJECTS OF THE INVENTION

It is an object of this invention to provide a method for lessening the production of fines from a gas-based direct reduction process.

It is also an object of the invention to provide means for achieving a steady-state operation of a gas-based direct reduction process at higher local temperatures and higher average temperatures than is possible with current processes.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a schematic process diagram showing the process and the apparatus for carrying out the invented process.

Figure 2 is a schematic view of a direct reduction furnace showing a typical temperature profile of the prior art.

Figure 3 is a schematic view of a direct reduction furnace showing a temperature profile when utilizing the invented process.

DETAILED DESCRIPTION

As shown in Figure 1, a direct reduction furnace 10 has an upper charging end with means 12 for charging lump ore and/or oxide pellets into the furnace to form a burden 14. The lower end 16 of the furnace has a discharge means for discharging the reduced metallized product from the furnace, and causing the burden to move downwardly as the metallized product is removed. At the middle of furnace is a reducing gas injection system 18 made up of a bustle and tuyeres. Hot reducing gas is injected into the furnace through the bustle and tuyeres.

Reacted reducing gas, or spent off-gas, principally carbon dioxide and steam, is removed from top of the furnace at 20, cleaned, and passed through a reformer 22 to change it to reducing gas, principally hydrogen and carbon monoxide, for reintroduction to the furnace through the bustle and tuyeres. The fuel gas 24 utilized for heating the reformer is combusted and results in a hot waste off-gas 25 from which heat is usually recovered. Combustion causes the waste gas to be oxidized, so that it is principally a mixture of nitrogen and carbon dioxide, which are inert, or at least non-reducing.

Lump ore feed is stored for a few months in stockpiles S before being reclaimed and stored in a bin 26. The stockpile storage is for a period of one months to several months, as necessary. This procedure allows the release of internal stresses, increasing the efficiency of the subsequent pre-drying, which has the objective of avoiding mechanical weakness of the lump ore during thermal shock and reduction at low temperatures. In accordance with the present invention, hot waste off-gas 25 is removed from the reformer heating chamber, may be passed through a heat recovery system, such as a boiler, is compressed, and passed through the storage bin 26 to heat the ore therein to at least about 200 degrees C, but preferably to at least 300C. The off-gas is introduced to the bin at a controlled temperature. The temperature of the off-gas can be tempered by introduction of cooling air 28, as necessary. After pre-drying of the

iron ore charge material, it is transported through a thermally insulated charging system 30 to the furnace, and is then introduced to the upper portion of the furnace to form the burden. A dynamic seal arrangement may be utilized to provide thermal insulation. Moisture in the lump iron ore is a problem which must be and is overcome by preheating and predrying the iron ore, which reduces the water content of the pellet or lump from about 4% to less than 0.5%.

The preheated iron ore increases in temperature from its introduction temperature of about 150C to more than 750C in less than 30 minutes, for an enhanced thermal profile. This can be done with a decrease in the H_2/CO ratio of the reformer gas, and with a reduction in the upflow volume of natural gas and reducing gas within the furnace.

Figure 3 shows the enhanced temperature profile in the direct reduction furnace when utilizing the invented process. This is to be compared to the prior art temperature profile shown in Figure 2, which shows that the present invention reduces the zone of low-temperature reduction.

Pre-drying the lump charge material requires subsequent separate charging of the lump ore, to avoid it re-acquiring moisture from the contact with pellets that have been submitted to a lime (CaO) coating process. The invented process requires very little additional operating cost as the waste gas from the reformer operation is already available.

While the invention has been described in relation to direct reduction plants that utilize gas reformers, in the event that an installation does not have reformers, a different heating mechanism is required. Also, if a reformer produces waste gas with insufficient heat content to raise the temperature of the charge material to about 200C, alternative heating mechanisms can be used.

SUMMARY OF THE ACHIEVEMENTS OF THE INVENTION

From the foregoing, it is readily apparent that we have invented an improved method and apparatus for pretreatment of solid lump feed material for gas and pellet/lump-based direct reduction processes, by initially storing the lump feed in stockpiles for stress release, followed by pre-drying the feed material prior to charging into the reduction furnace and finally increasing the average temperature of the reduction furnace, in order to reduce the amount of reduction at low temperatures, thereby minimizing the formation of fines within the furnace.

It is to be understood that the foregoing description and specific embodiments are merely illustrative of the best mode of the invention and the principles thereof, and that various modifications and additions may be made to the method and apparatus by those skilled in the art, without departing from the spirit and scope of this invention, which is therefore understood to be limited only by the scope of the appended claims.